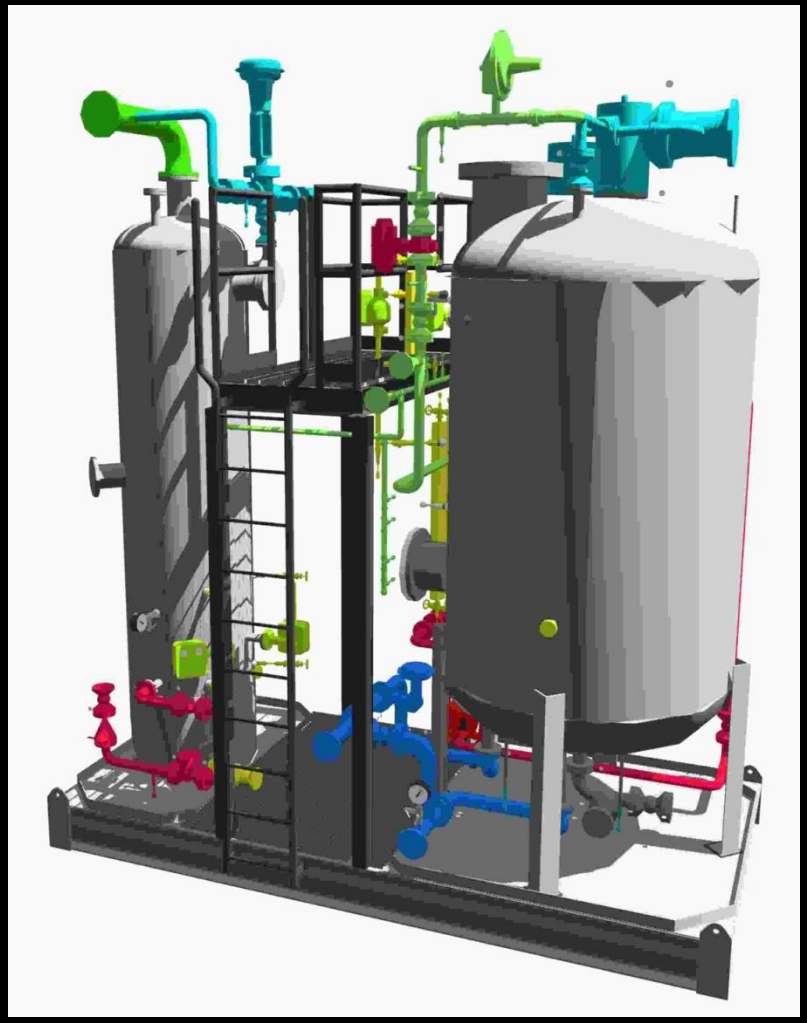
AØ RF-Gun Cooling System



Presented by:

Danielle Hannah

Supervised by:

Maurice Ball

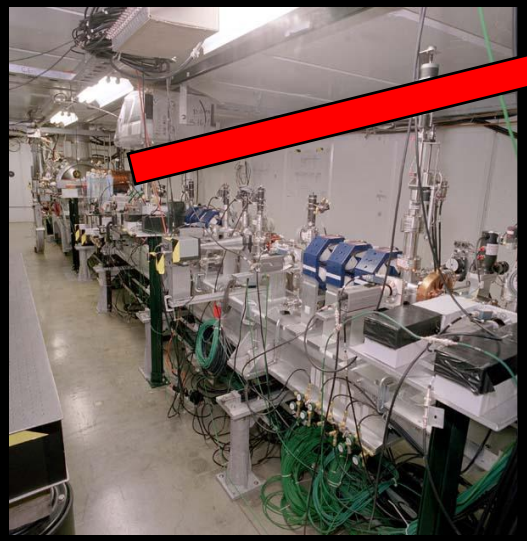
Jamie Santucci

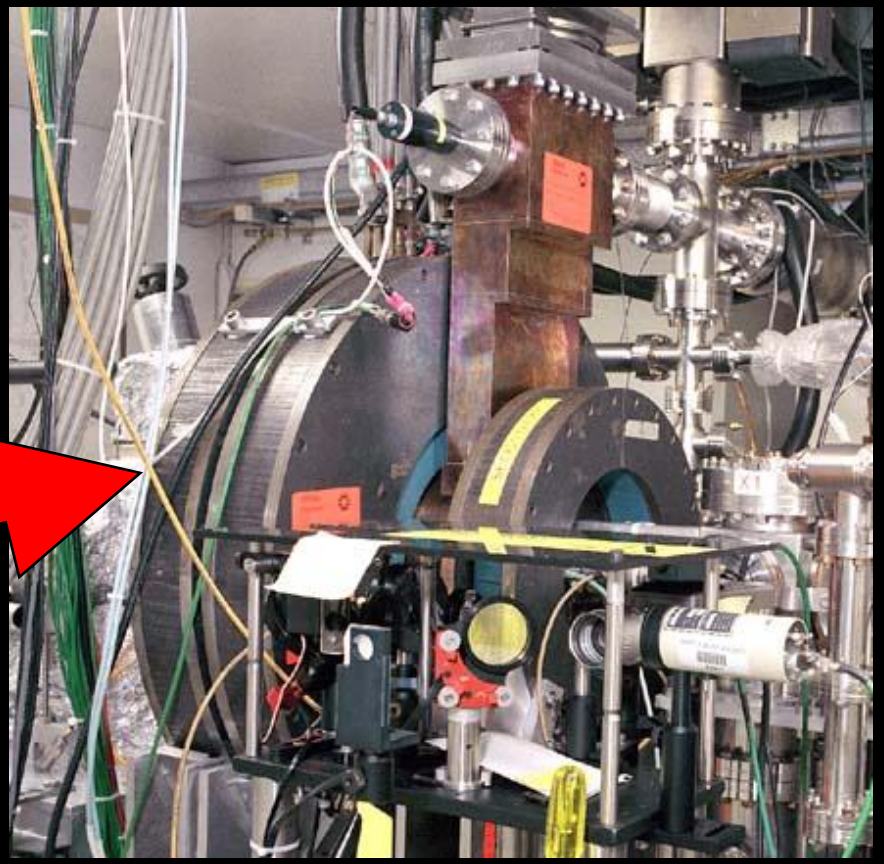
Danielle N. Hannah

- Born and raised in Marietta, Georgia
- Spelman College/North Carolina A&T
  - Dual Degree Engineering Program (DDEP)
    - B.A. Mathematics and B.A. Architectural Engineering
  - Rising Junior
- Summer Internships in Science and Technology **(SIST)**

AØ Experiment

- The AØ Photoinjector (AØPI) facility is a small research and development program section within the Accelerator Division (AD).
- An essential component of the overall AØPI is a Radio Frequency Electron Gun (RF-gun).
- The RF-gun is located in the south cave of the AØ building.
- This gun consists of cavities that are used to accelerate a beam of electrons.

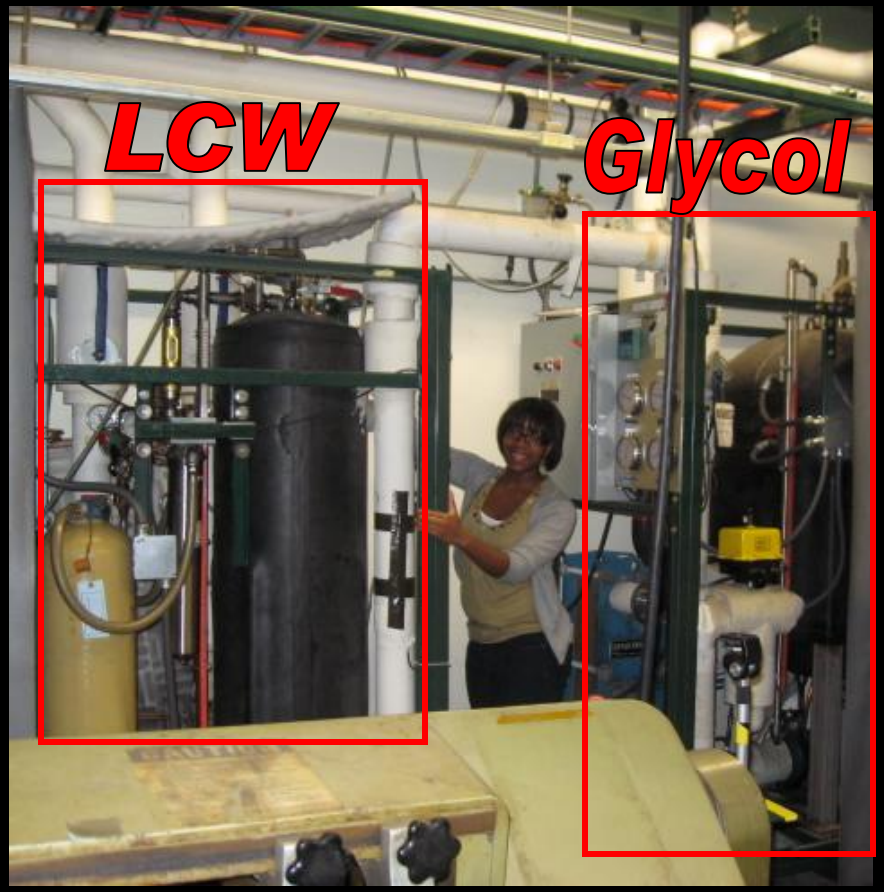




Project Background

- The RF-gun emits heat.
- This poses a problem to the well-being of the machine and the physicists.

❖ **Engineers of the Mechanical Support Department created a low-conductivity water (LCW) skid cooling system to keep the RF-gun at a consistent temperature.**



- Within the next 5 years, a new RF-gun will be installed in the AØ north cave.
- The new RF-gun will use the same cooling system as the current gun.

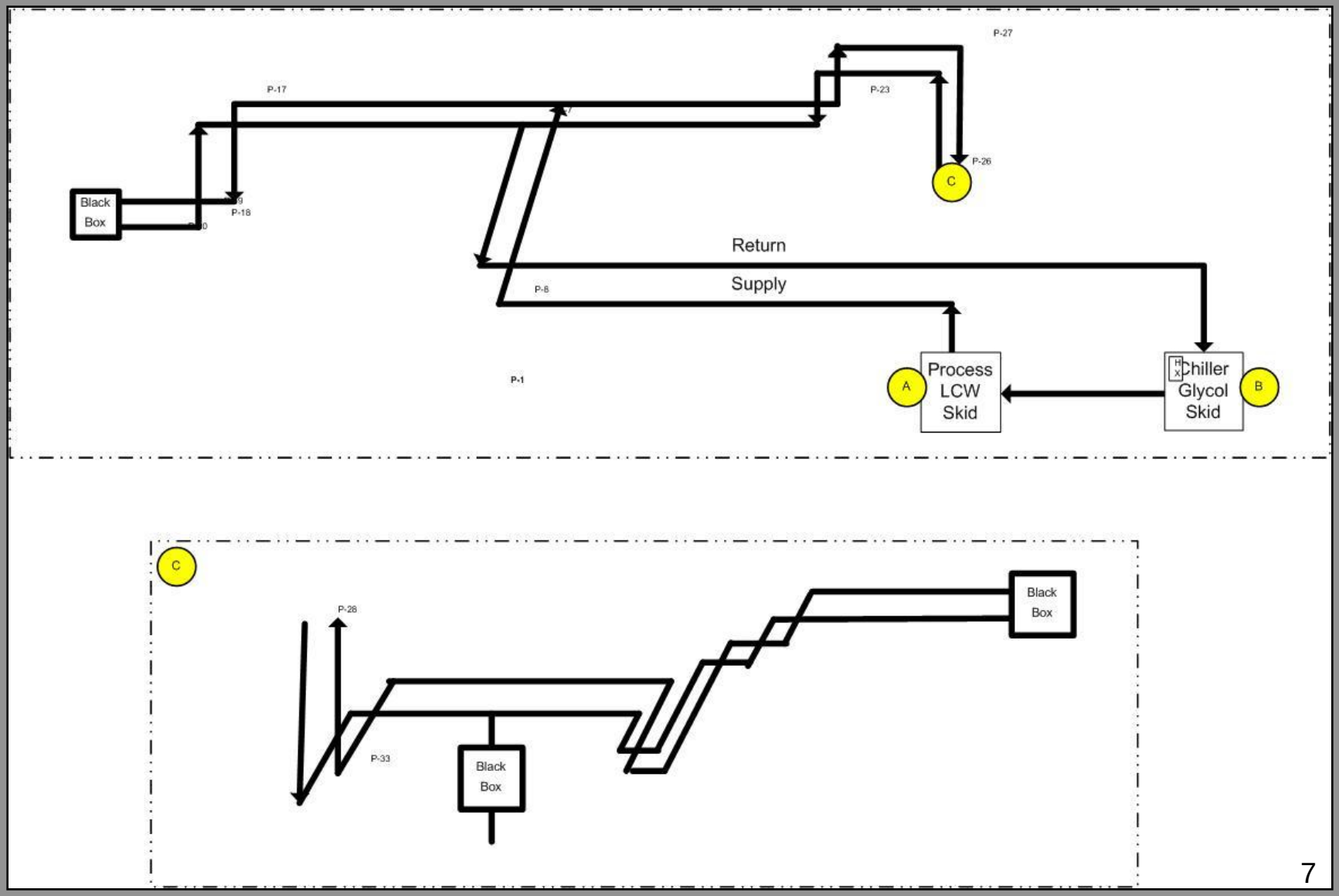
❖ **But before the installation occurs it must be assured that the current cooling system for the AØ PI RF-gun is up to par.**

Project Description

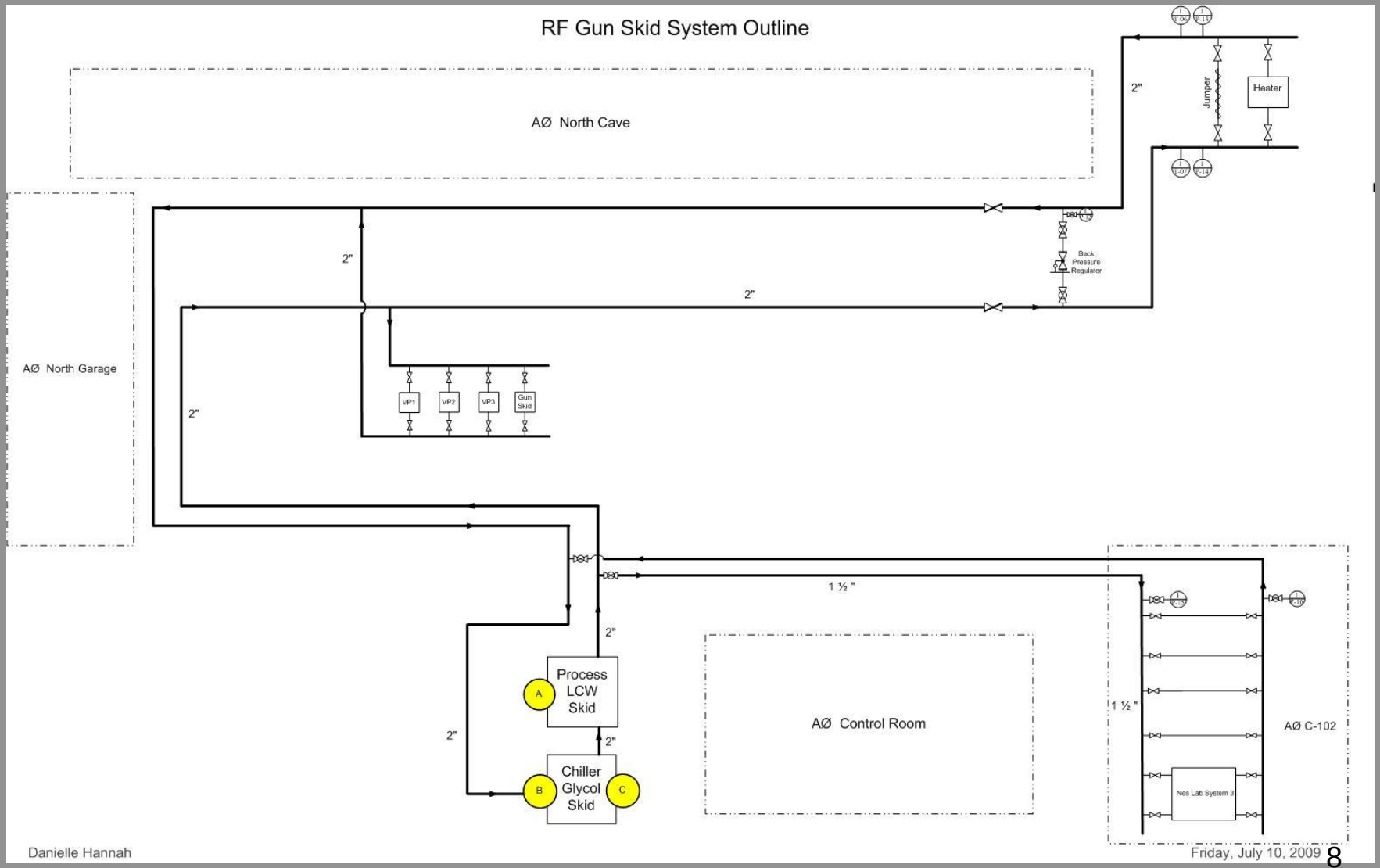
- This presents how the AØ PI RF-gun skid system was characterized, improved, and documented over the course of a summer.
- In order to obtain these goals the following steps had to be executed:
  - Outlined spreadsheet acting as a project timeline,
  - Development of a detailed system schematic,
  - Refinement of the system's appearance,
  - Completed fluid analysis throughout system.

System Schematic

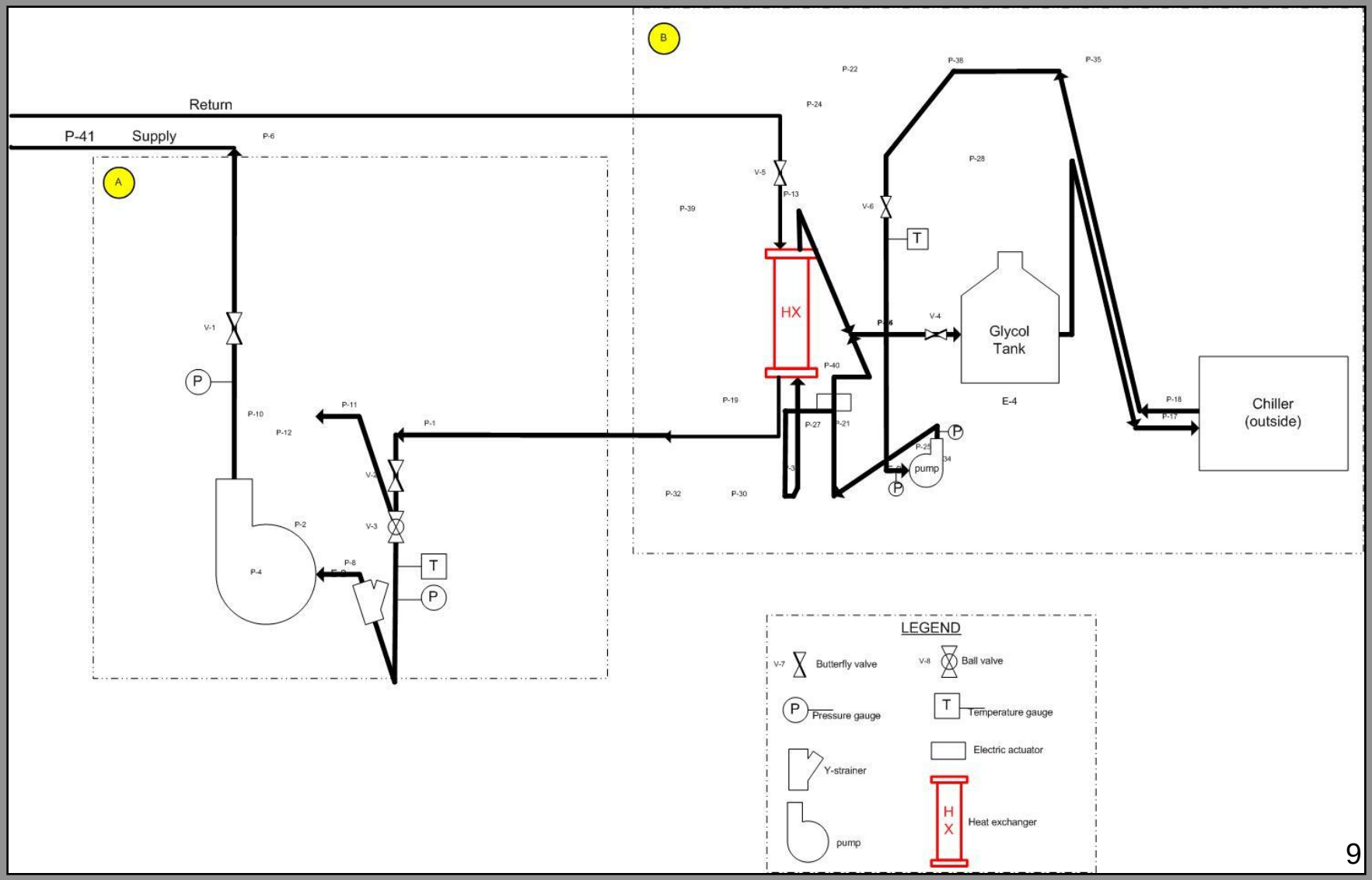
Draft #1


P-27
P-17
P-23
P-26
C
Black
Box
P-18
Return
Supply
P-8
P-1
A
Process
LCW
Skid
Chiller
Glycol
Skid
B
C
P-28
Black
Box
P-33
Black
Box

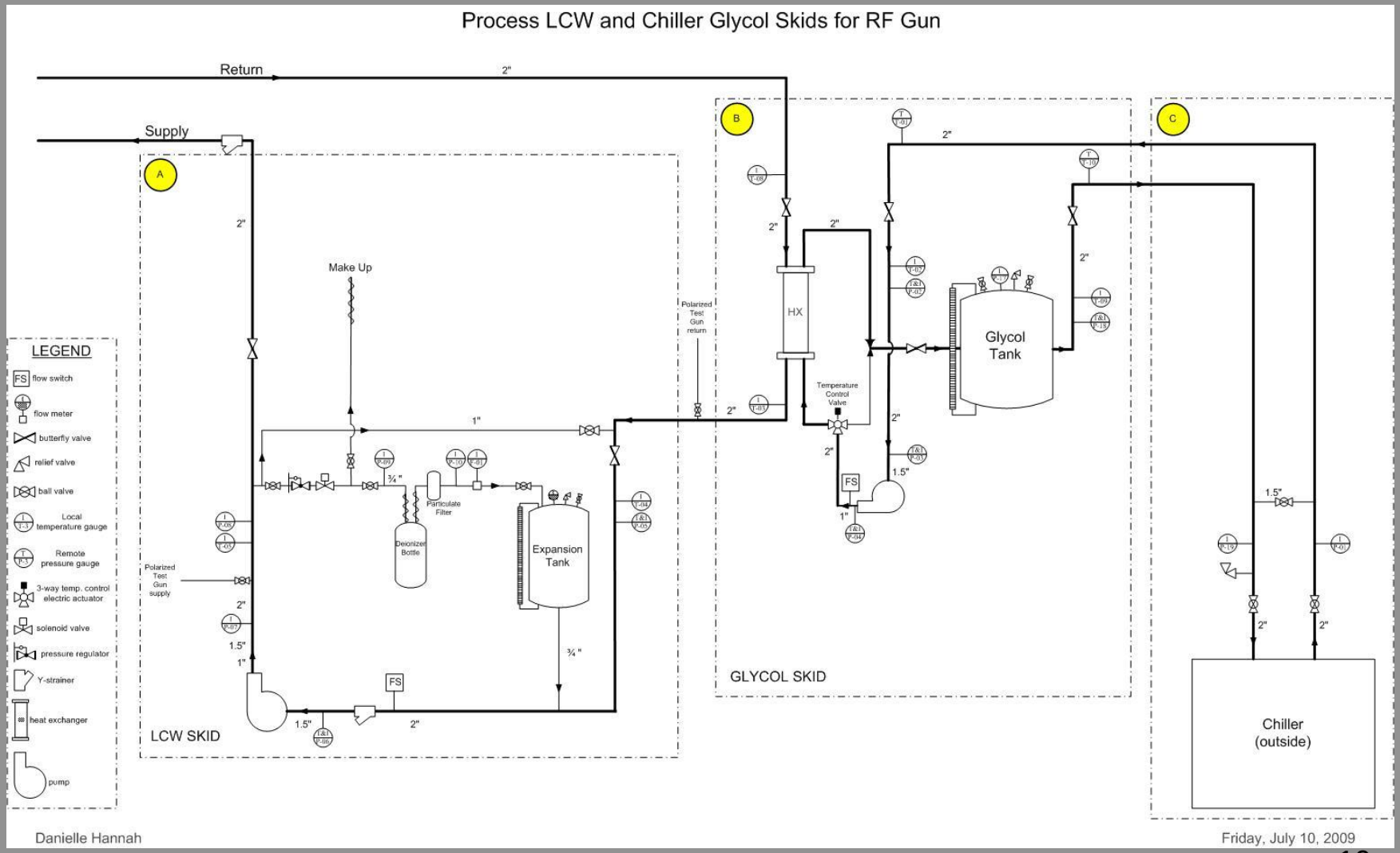
Final Draft


RF Gun Skid System Outline
AØ North Cave
AØ North Garage
AØ Control Room
AØ C-102
2"
Jumper
Heater
Back Pressure Regulator
VP1
VP2
VP3
Gun Skid
1 ½ "
Process LCW Skid
Chiller Glycol Skid
A
B
C
Nes Lab System 3
Danielle Hannah
Friday, July 10, 2009

Draft #1

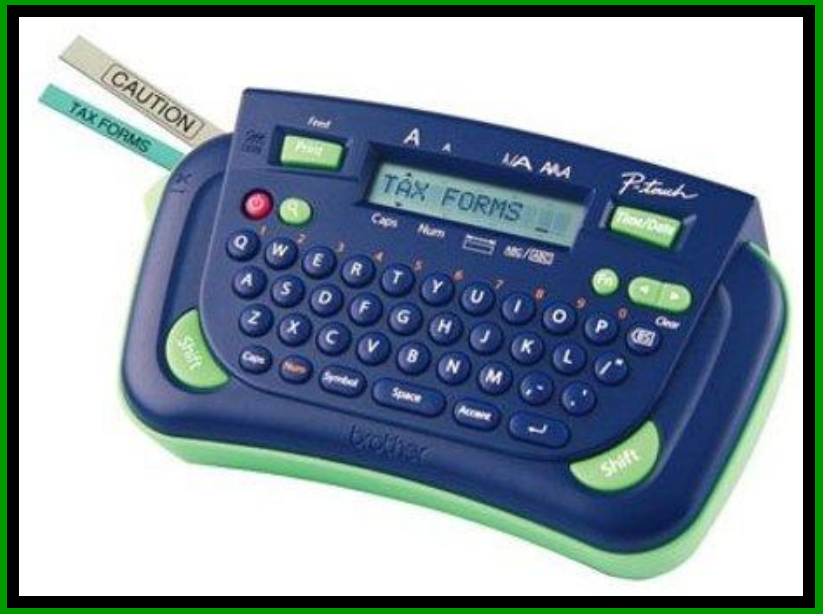

Return
P-41
Supply
P-6
A
B
P-22
P-38
P-35
P-24
P-28
V-5
P-13
V-6
P-39
T
HX
V-4
Glycol Tank
E-4
P-40
P-19
P-18
P-17
Chiller (outside)
V-1
P
P-10
P-11
P-12
P-1
P-27
P-21
P-25
pump
P-32
P-30
P-2
V-3
P-4
P-8
LEGEND
V-7
Butterfly valve
V-8
Ball valve
Pressure gauge
Temperature gauge
Electric actuator
Y-strainer
pump
H X
Heat exchanger

Final Draft

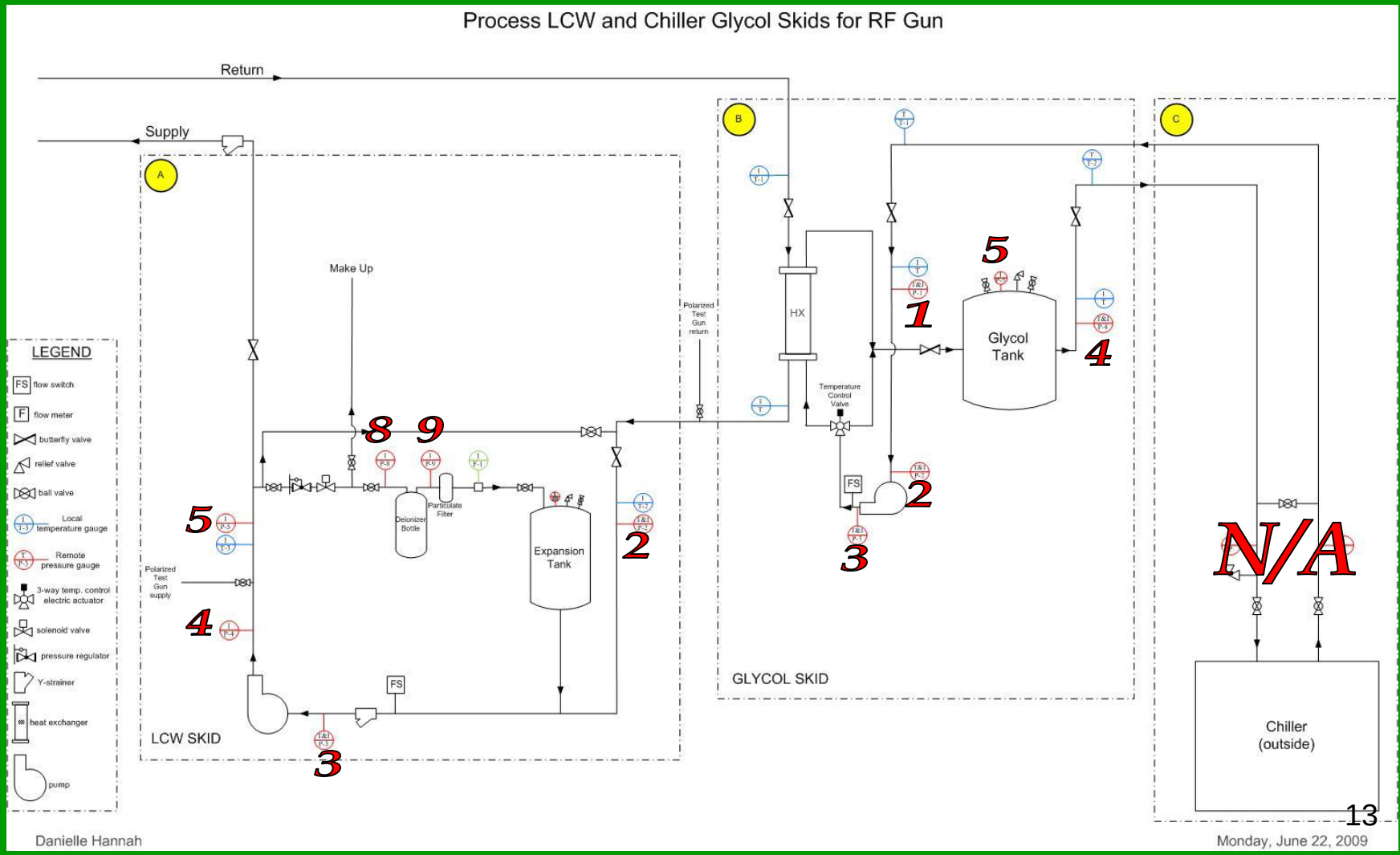

Process LCW and Chiller Glycol Skids for RF Gun
Return
Supply
2"
A
B
C
Make Up
1"
¾ "
Particulate Filter
Deionizer Bottle
Expansion Tank
Polarized Test Gun supply
Polarized Test Gun return
1.5"
FS
LCW SKID
HX
Temperature Control Valve
Glycol Tank
GLYCOL SKID
Chiller (outside)
LEGEND
flow switch
flow meter
butterfly valve
relief valve
ball valve
Local temperature gauge
Remote pressure gauge
3-way temp. control electric actuator
solenoid valve
pressure regulator
Y-strainer
heat exchanger
pump
Danielle Hannah
Friday, July 10, 2009

System Updates

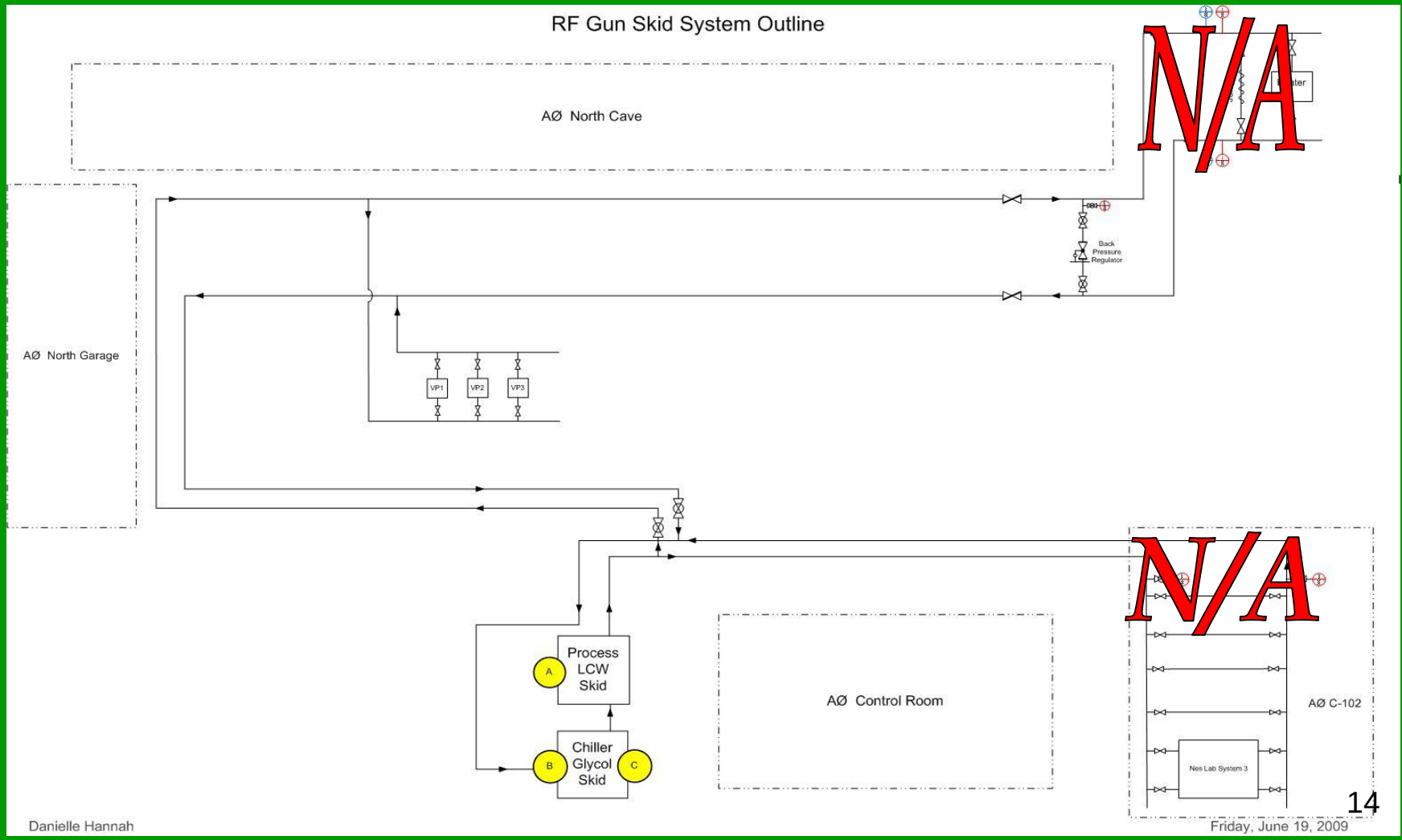
Re-Labeling


CAUTION
TAX FORMS
TAX FORMS
Print
Caps
Num
Shift
Space
Shift

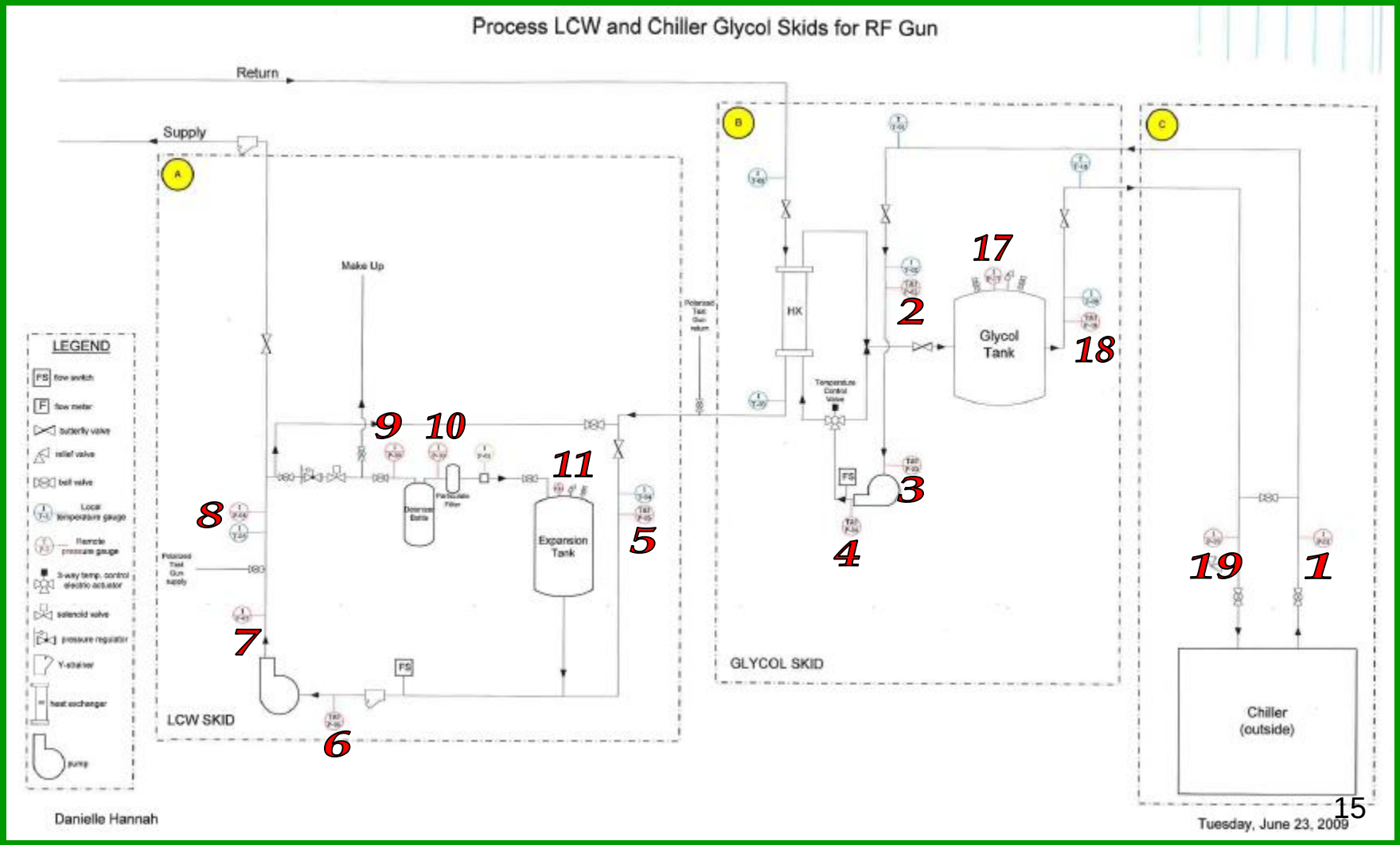
Original Labels



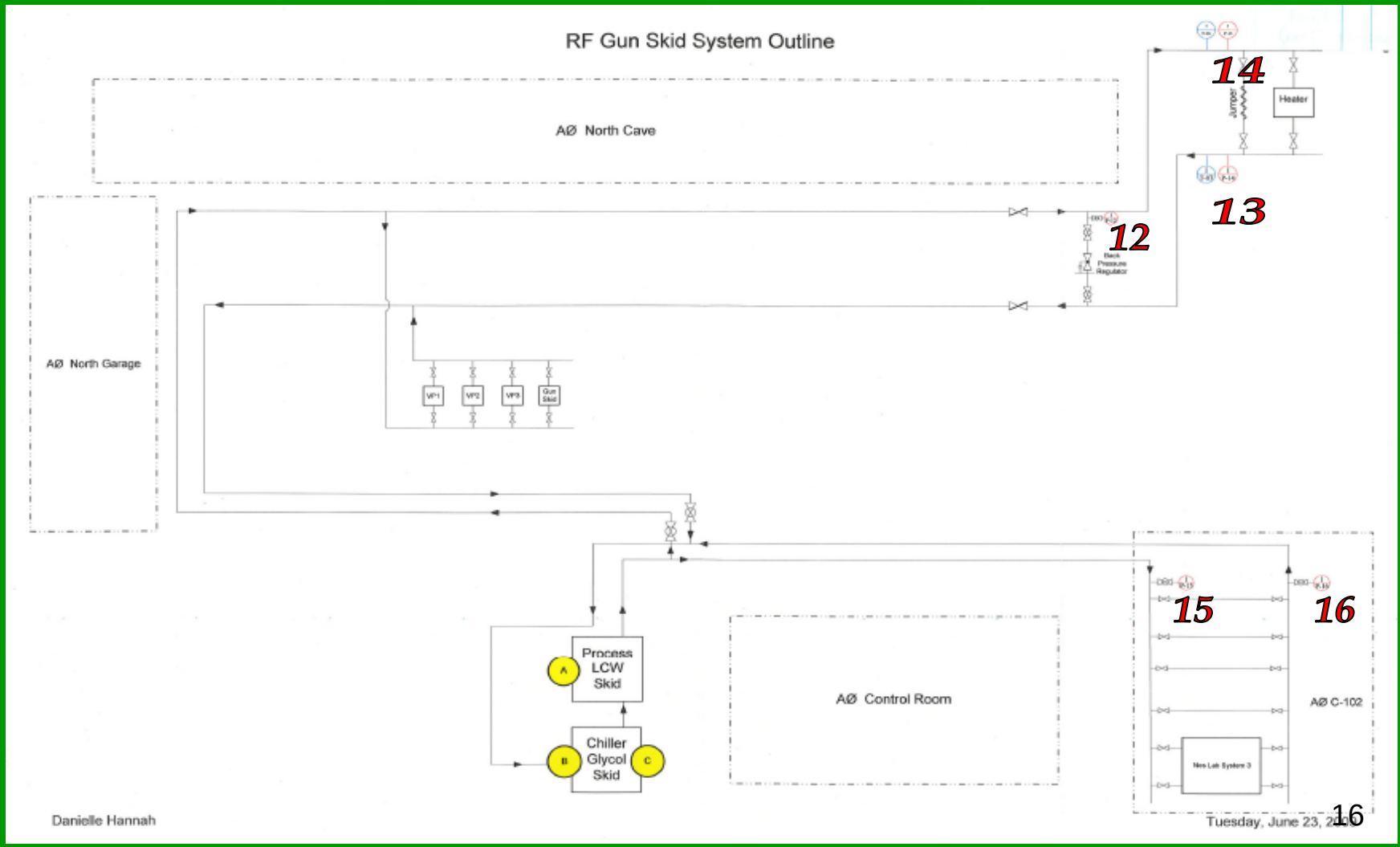
Original Labels

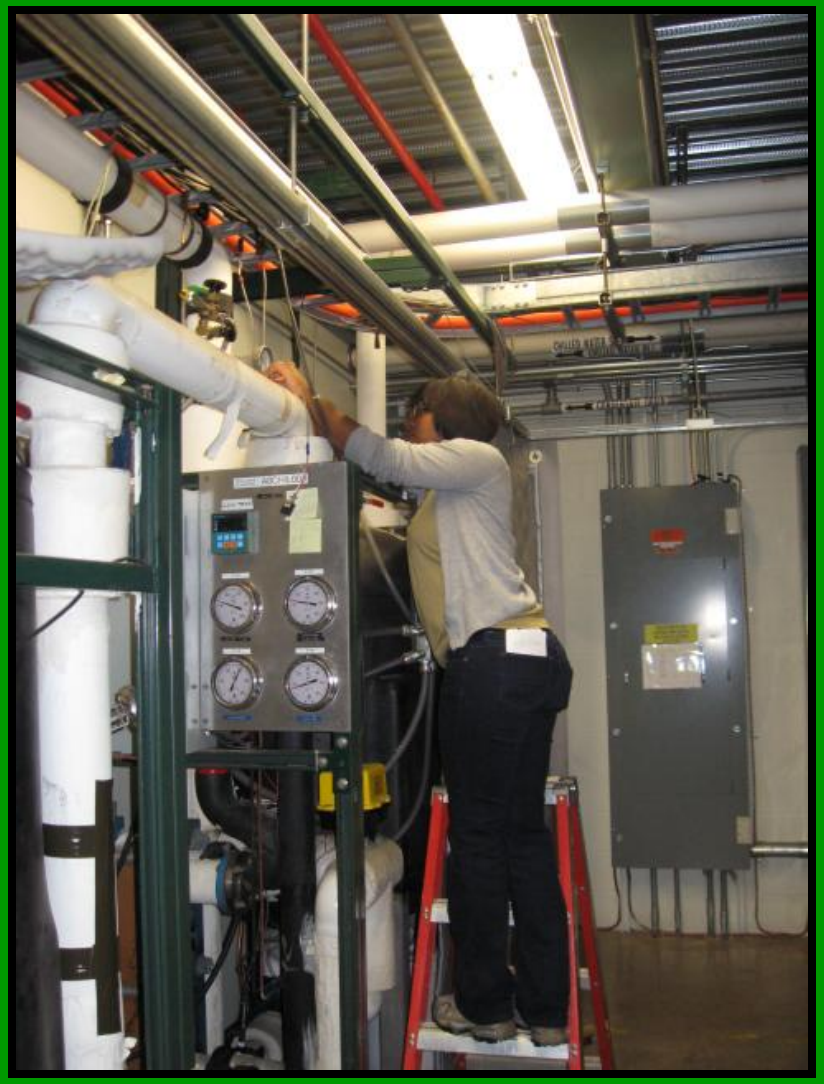


New Labels


Process LCW and Chiller Glycol Skids for RF Gun
Return
Supply
Make Up
LEGEND
LCW SKID
GLYCOL SKID
HX
Glycol Tank
Expansion Tank
Chiller (outside)
1
2
3
4
5
6
7
8
9
10
11
17
18
19
Danielle Hannah
Tuesday, June 23, 2009

New Labels


RF Gun Skid System Outline
AØ North Cave
AØ North Garage
14
13
12
Heater
Jumper
Back Pressure Regulator
VP1
VP2
VP3
Gun Skid
Process LCW Skid
Chiller Glycol Skid
A
B
C
AØ Control Room
15
16
AØ C-102
Danielle Hannah
Tuesday, June 23, 2009

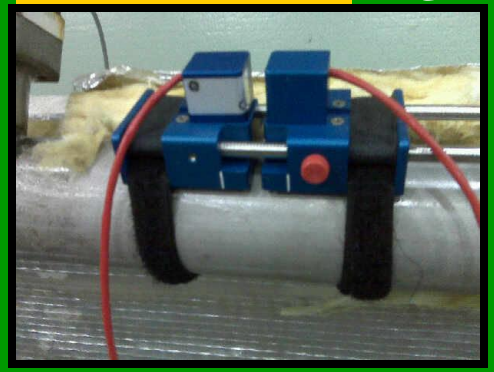



T-01
CAUTION

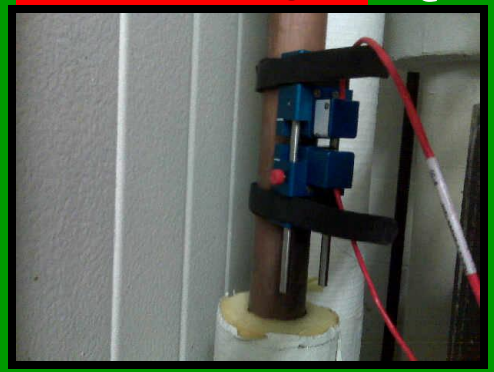
Flow Rate Measurements

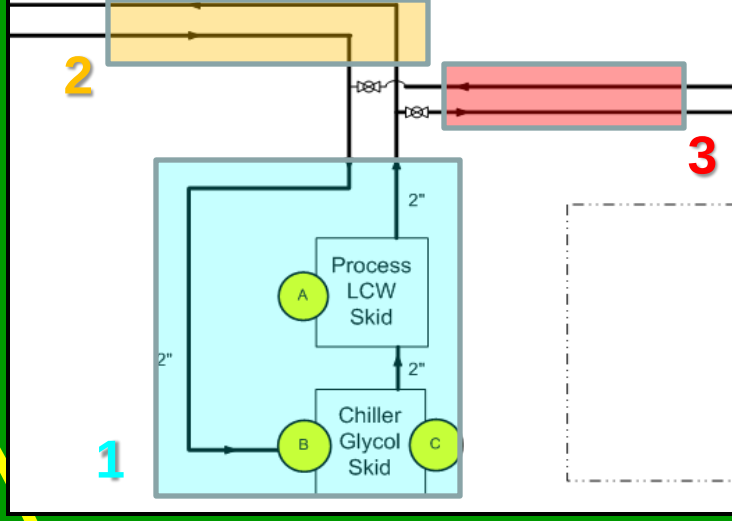
Section 1: Q = 30.0 gpm

Section 2: Q = 24.4 gpm



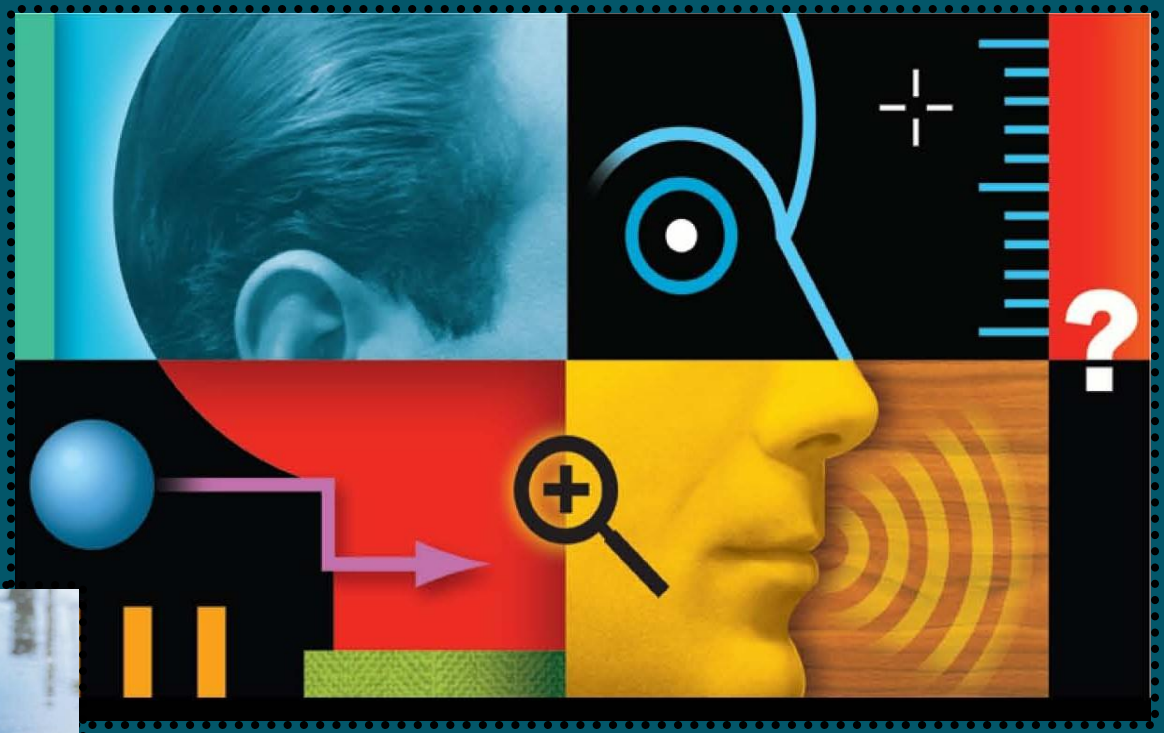
Section 3: Q = 5.5 gpm





Q = 29.9 gpm

Flow Fluid Analysis



Bernoulli's Principle

- The most useful single equation in fluid mechanics.
- States that for an inviscid flow, an increase in the speed of the fluid occurs simultaneously with a decrease in pressure.

$$z_1 + \frac{144\,p_1}{\rho_1} + \frac{v_1^2}{2g} = z_2 + \frac{144\,p_2}{\rho_2} + \frac{v_2^2}{2g} + h_L$$

Equation 1

$$[elev.head]_1 + [press.head]_1 + [vel.head]_1 = [elev.head]_2 + [press.head]_2 + [vel.head]_2$$

Fluid Flow Analysis

- Bernoulli's Equation (Equation 1) can be expressed as:

$$P_1 - P_2 = \frac{\rho}{144} + \frac{v_2^2 - v_1^2}{2g} + h_L$$ Equation 2

in order to calculate the change in pressure from P_1 to P_2.

$$h_L = \frac{0.00259 K Q^2}{d^4}$$ Equation 3

$$K = \frac{fL}{D}$$ Equation 4

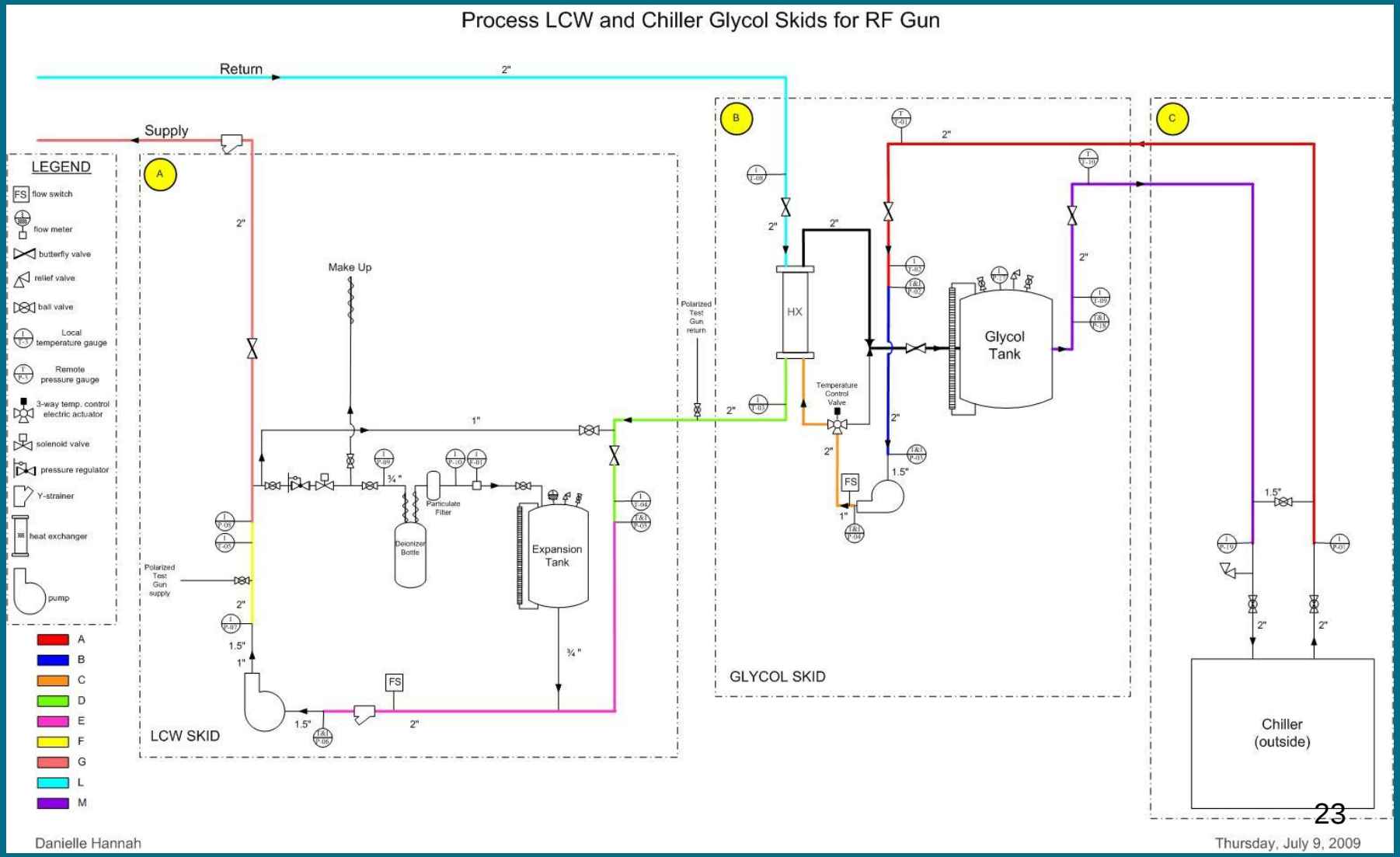
$$R_e = \frac{50.6 Q \rho}{d \mu}$$ Equation 5

$$f = \frac{64}{R_e}$$ Equation 6

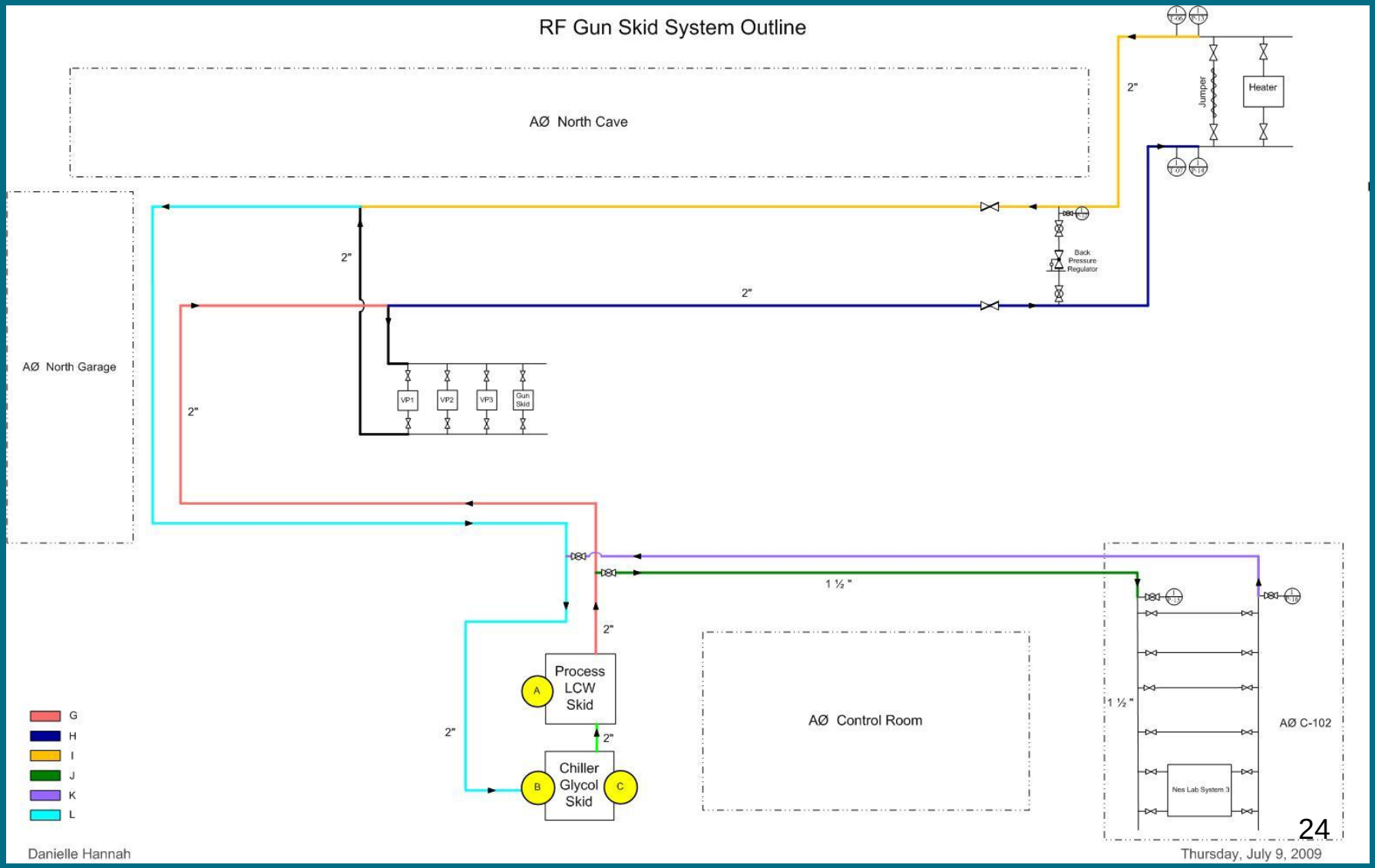
[h_L=head loss (ft), Re=Reynold's number, K=resistance coefficient, Z=elevation (ft), P=pressure (psi), ρ=weight density (lb/ft^3), v=velocity (ft/s), μ=absolute viscosity (cP), d=diameter (in), D=diameter (ft), f=friction factor, Q=rate of flow (gpm), L=pipe length (ft), g=acceleration of gravity (ft/s^2)]

- In efforts to minimize errors, the entire system was separated into 13 sections (A-M).

Sections A-G, L-M



Sections G-L


RF Gun Skid System Outline
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Gun Skid
1 ½ "
Process LCW Skid
Chiller Glycol Skid
A
B
C
G
H
I
J
K
L
Nes Lab System 3
Danielle Hannah
Thursday, July 9, 2009

Pressure Drop Calculation: Section A

Given:

- $f_T = 0.019$
- $\mu = 1.7$ cP
- $\rho = 62.42$ lb/ft^3
- $v = 2.87$ ft/s

Measured:

- $d = 0.17225$ ft
- $Z_2 = 9.833$ ft
- $Z_1 = 0$ ft
- $L = 69.5$ ft
- $Q = 30$ gpm

Assumptions:

- All fittings are standard 45 or 90 elbows.

Calculations:

- $R_e = \frac{50.6}{2.067in} * \frac{30gal}{\min} * \frac{62.42lb}{ft^3} * \frac{1}{1.7cP} = \frac{94753.6}{3.5139} = 2.7 \times 10^4$
- f = **0.026**
- $K = \frac{0.026 * 69.5\,ft * 12in}{2.067in * ft} = \frac{21.684}{2.067} = 10.490$
  - 45 = $16f_T \rightarrow 2 * 16 * 0.019 = 0.608$
  - 90 = $30f_T \rightarrow 12 * 30 * 0.019 = 6.84$
- $K_{TOTAL} = 0.608 + 6.84 + 10.49 = 17.95$
- $h_L = 0.00259 * \frac{17.95 * 30gal^2}{2.067in^4 * \min} = \frac{41.84}{18.254} = 2.292$ ft
- **ΔP =** $\frac{62.42lb * ft^2}{144in^2 * ft^3} (9.833\,ft + 0\,ft + 2.292\,ft)$ **= 5.256 psi**

Total System Pressure Drop

- Section A = 5.256 psi
- Section B = 1.664 psi
- Section C = 0.893 psi
- Section D = 2.484 psi
- Section E = 1.398 psi
- Section F = 1.061 psi
- Section G = 5.174 psi
- Section H = 1.423 psi
- Section I = 1.134 psi
- Section J = 4.213 psi
- Section K = 4.444 psi
- Section L = 5.561 psi
- Section M = 3.909 psi

AØ RF-Gun Skid System gauge readings

Pressure Gauge	psi		Temperature Gauge	F
P-01	33		T-01	53
P-02	13		T-02	36
P-03	7.5		T-03	51
P-04	62.5		T-04	50.5
P-05	9		T-05	65
P-06	7		T-06	45
P-07	140		T-07	60
P-08	137		T-08	58
P-09	19		T-09	44
P-10	9.5		T-10	82
P-11	5			
P-12	141			
P-13	135			
P-14	10			
P-15	54			
P-16	10			
P-17	22			
P-18	25			
P-19	22			

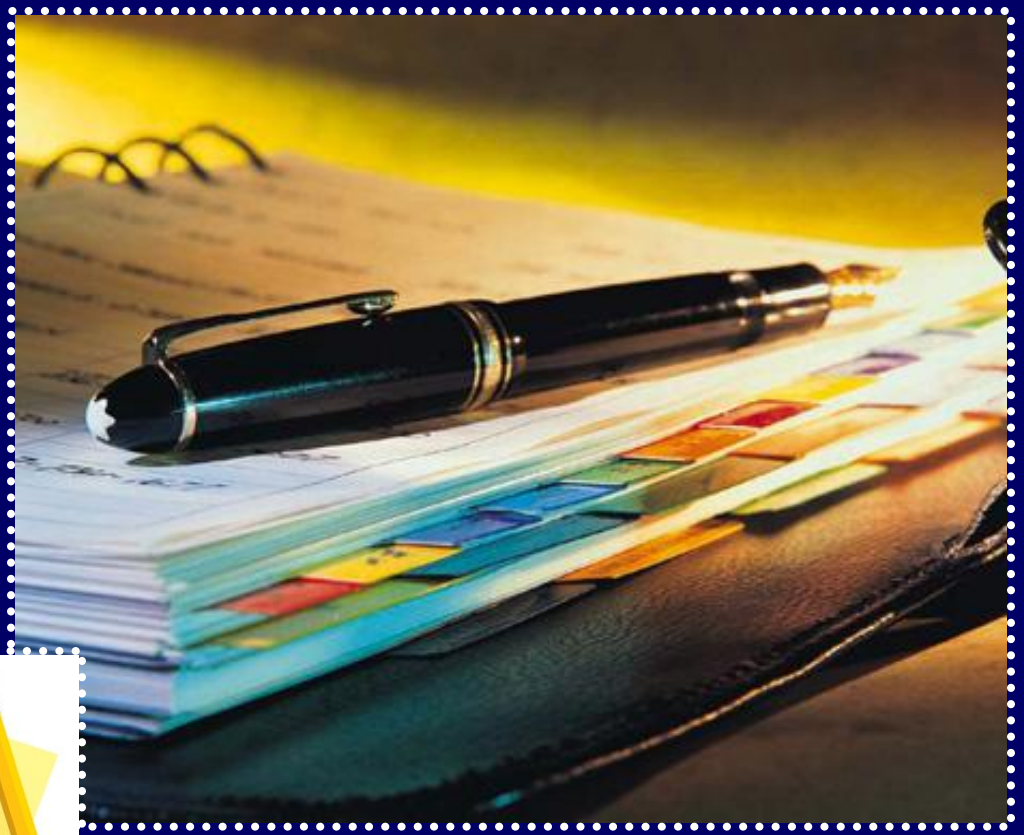
Section A + B + C +…K + L + M =

38.614 psi or 89.198 ft

Entire Gauge Pressure Drop =

134 psi or 309.54 ft

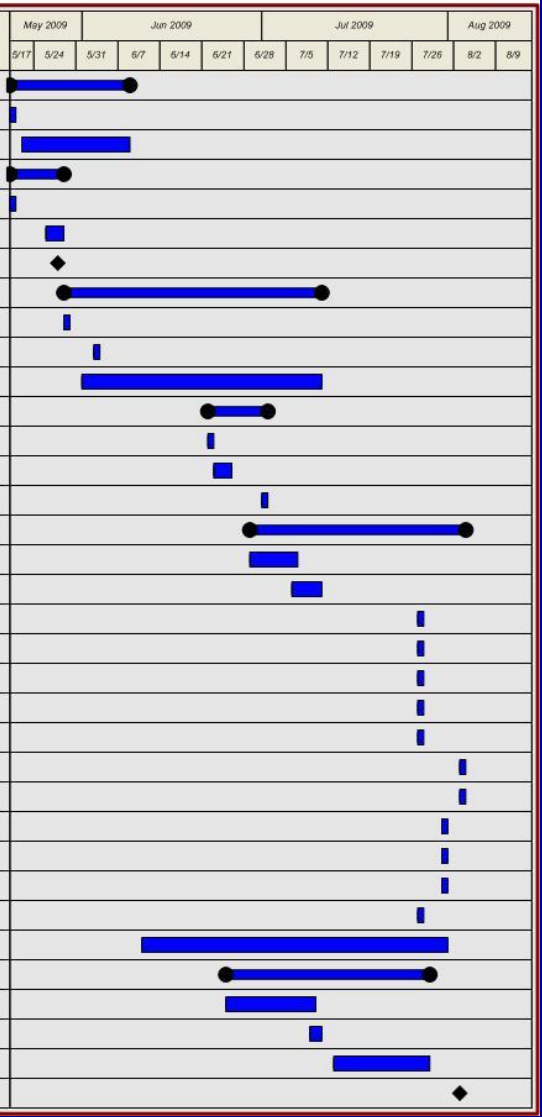
Project Timeline



Project Manager

AØ RF Gun Skid System

ID	Task Name	Start	Finish	Duration
1	**Fluid Mechanics review**	**5/20/2009**	**6/8/2009**	**14d**
2	Read Sections 1.1-1.6	5/20/2009	5/20/2009	1d
3	Work Problems 4.14-4.15	5/22/2009	6/8/2009	12d
4	**Schematic introduction**	**5/20/2009**	**5/28/2009**	**7d**
5	Highlight E-size main pipelines	5/20/2009	5/20/2009	1d
6	Re-create HINS-LCW Skid in Visio	5/26/2009	5/28/2009	3d
7	Project Manager	5/28/2009	5/28/2009	0d
8	**LCW Schematic in Visio**	**5/29/2009**	**7/10/2009**	**31d**
9	Complete a walk-through to sketch out skid layouts	5/29/2009	5/29/2009	1d
10	Study pressure drops, temperature changes, valves, etc.	6/3/2009	6/3/2009	1d
11	Create LCW system schematic	6/1/2009	7/10/2009	30d
12	**Improving the skid system**	**6/22/2009**	**7/1/2009**	**8d**
13	Measure piping throughout system	6/22/2009	6/22/2009	1d
14	Re-label all gauges throughout system	6/23/2009	6/25/2009	3d
15	Create Excel spreadsheet for gauge readings	7/1/2009	7/1/2009	1d
16	**Calculation Support**	**6/29/2009**	**8/3/2009**	**26d**
17	Verify pressure drop from P-01 to P-02 (A)	6/29/2009	7/6/2009	6d
18	Verify pressure drop from P-01 to P-02 (B)	7/6/2009	7/10/2009	5d
19	Verify pressure drop from P-01 to P-02 (C)	7/27/2009	7/27/2009	1d
20	Verify pressure drop from P-01 to P-02 (D)	7/27/2009	7/27/2009	1d
21	Verify pressure drop from P-01 to P-02 (E)	7/27/2009	7/27/2009	1d
22	Verify pressure drop from P-01 to P-02 (F)	7/27/2009	7/27/2009	1d
23	Verify pressure drop from P-01 to P-02 (G)	7/27/2009	7/27/2009	1d
24	Verify pressure drop from P-01 to P-02 (H)	8/3/2009	8/3/2009	1d
25	Verify pressure drop from P-01 to P-02 (I)	8/3/2009	8/3/2009	1d
26	Verify pressure drop from P-01 to P-02 (J)	7/31/2009	7/31/2009	1d
27	Verify pressure drop from P-01 to P-02 (K)	7/31/2009	7/31/2009	1d
28	Verify pressure drop from P-01 to P-02 (L)	7/31/2009	7/31/2009	1d
29	Verify pressure drop from P-01 to P-02 (M)	7/27/2009	7/27/2009	1d
30	Project: PowerPoint Presentation	6/11/2009	7/31/2009	37d
31	**Project: Scientific Paper**	**6/25/2009**	**7/28/2009**	**24d**
32	Write Introduction	6/25/2009	7/9/2009	11d
33	Title Page	7/9/2009	7/10/2009	2d
34	Methods	7/13/2009	7/28/2009	12d
35	Specify instrumentation	8/3/2009	8/3/2009	0d



Summary

- A system schematic was perfected
- The entire system's temperature and pressure gauges were re-labeled
- The drop in pressure *(calculated)* throughout the system was compared with the drop in pressure *(readings)* to conclude that the gauge readings were inaccurate.

➢ **Thus, the current cooling system is not up to par.**

Future Goals

- Develop a procedure to switch RF-gun cooling back and forth from North Cave to South Cave
- Develop instrumentation for the system to data log on ACNET, a control system that accelerators use.

Acknowledgments

- Maurice Ball, AD, Engineering, Mechanical Support Dept.
- Jamie Santucci, AD, Photoinjector
- Elmie Peoples-Evans, APC High Intensity Neutrino Source Dept.
- David Peterson, AD, Antiproton Source Dept.
- Dr. James Davenport, SIST founder
- Dianne Engram, Workforce Development & Resources, Equal Opportunity & Counseling, SIST director
- 2009 SIST interns, staff, and committee
- Fermi National Accelerator Laboratory